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Mould Filling of Ag-Pd-Cu-Au and Ag-Zn-Sn-In Alloy Castings made using a Rapidly Prepared Gypsum-bonded Investment Material

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Abstract - *Mandibular premolar-shaped wax patterns of full crowns with a marginal angle of 30° were prepared. Two semiprecious alloys were cast using a rapidly prepared gypsum-bonded investment material or a conventional gypsum-bonded investment. A precise impression was taken and cut into four segments. Scanning electron microscopy was used to evaluate the mould filling of each segment. The mould filling of the silver-palladium-copper-gold alloy was worse than that of the silver-zinc-tin-indium alloy. The mould filling of both alloys cast with the rapidly prepared gypsum-bonded investment material was superior to that using the conventional investment.*

KEY WORDS: casting, investment material, margin, mould filling, semiprecious alloy

INTRODUCTION

Some properties of silver-palladium-copper-gold (Ag-Pd-Cu-Au) alloys have been studied, specifically the age-hardening mechanism[1], structure after heat treatments[2,3], ductility[4], tarnish and corrosion behaviour[5,6], biocompatibility[7], recastability[8] and clinical behaviour[9]. The corrosion behaviour[10] of silver-based alloys containing no gold, such as silver-tin-zinc, silver-indium or silver-zinc-tin-indium (Ag-Zn-Sn-In) alloys, was also investigated. Silver-based alloys have been endorsed for use in posts and cores[11], mainly for economic reasons. These two types of alloys have been commonly used as substitutes for gold alloys in clinical practice.

The accelerated casting technique has great advantages in dental casting procedures. Since the first attempt was made to shorten the time required to make a crown using the lost wax method[12], the accelerated casting technique has been promoted, mainly for phosphate-bonded investment material[13-18]. Among these studies, there were a few that evaluated the marginal fit of complete crowns made with the conventional and the accelerated casting techniques[16,17]. Little information, however, is available about the effect of rapidly prepared gypsum-bonded investment material on the mould filling of semiprecious alloys. The purpose of the present study was to investigate the mould filling ability of Ag-Pd-Cu-Au and Ag-Zn-Sn-In alloys cast using a rapidly prepared gypsum-bonded investment material.

MATERIALS AND METHODS

Table 1 lists the two metals (Castwell M.C.12, Miro Bright) tested in this study with their chemical compositions (wt%), density, and liquidus temperatures. The two investment materials tested were a rapidly prepared gypsum-bonded investment material (Cristoquick 20) and a conventional gypsum-bonded investment (Cristobalite Micro II).

A master die with a uniform sharp cervical margin of 30°, as described by Brockhurst *et al.*[19], was machined from a stainless steel rod. The shape and dimensions of the die were based on an Australian Standard (AS 1620, 1985) (Fig. 1). Wax patterns (Inlay wax medium, Inlay wax margin) of a crown with a 2.0-mm thick occlusal surface and a cylindrical outer form as uniformly thick as possible were prepared on the die according to a conventional dental laboratory technique. Special attention was paid to carving the fine margin on the test pattern using a sharp razor blade. The marginal sharpness of the pattern was checked with an optical microscope to select good patterns with high-quality margins. A sprue rod (1.0 mm diameter, approximately 3 mm long) was vertically connected to the center of the flat occlusal plane. The distance from the top of the pattern to the top rim of the casting ring was approximately 10 mm. The casting rings were lined with 1 layer of a ring liner (New casting liner No. 13). The wax pattern was vacuum-invested for 45 sec in a casting ring with either a rapidly prepared gypsum-bonded investment material or a conventional investment using a blade-driven vacuum mixer (Vacuum Power Mixer Plus). All mixing and investing procedures were carried out at room temperature. Twenty min after the end of investing, the invested mould of the rapidly prepared gypsum-bonded investment material was burned out in a furnace (KDF-009H) at 700°C for 30 min. The conventionally invested mould was allowed to bench-set at room temperature for 120 min and then heated to 200°C and held for 30 min, heated at 400°C for 30 min, and held at 700°C for 30 min in the furnace.

The two alloys were then cast using a spring-driven centrifugal casting machine (Centrifico casting machine). In this study, once the metal ingot had reached the casting

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Table 1. *Chemical compositions (wt%), densities and liquidus temperatures of silver-palladium-copper-gold and silver-zinc-tin-indium alloy*

Alloy	*Chemical composition*	*Density*	*Liquidus temperature*
Ag-Pd-Cu-Au alloy	Ag 46%, Pd 20%, Cu 20%, Au 12%, others 2%	11.5	930
Ag-Zn-Sn-In alloy	Ag 72%, Zn 13%, Sn 9%, In 6%	9.5	660

The data were obtained from the manufacturer's product information literature.

Table 2. *Mould filling index (μm)*

Alloy	*Ag-Zn-Sn-In alloy*			*Ag-Pd-Cu-Au alloy*		
Investment material	Mean	SD	Range	Mean	SD	Range
Rapidly prepared gypsum-bonded	70.8	12.5	50-80	20.0	8.8	10-35
Conventional gypsum-bonded	107.1	19.1	81-135	41.0	9.1	30-55

SD: standard deviation.

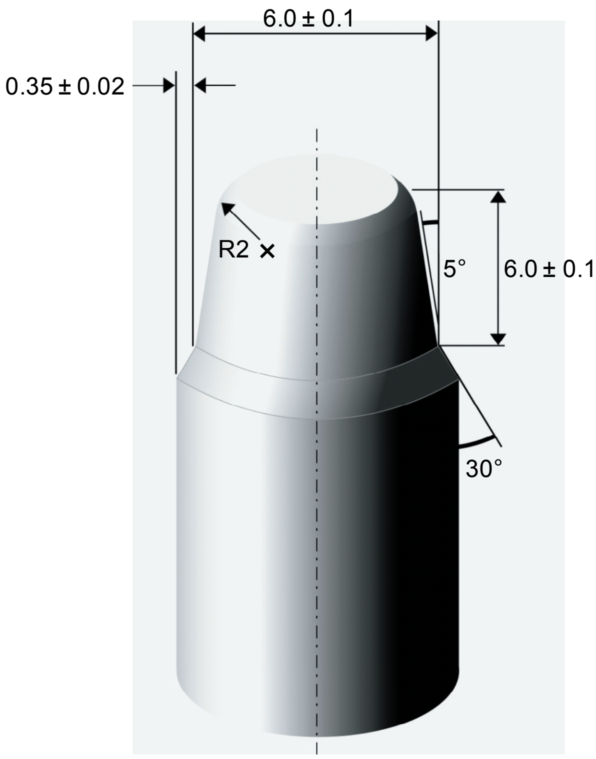

Figure 1. *Shape and dimensions (mm) of metal die for preparation of wax patterns.*

temperature and the heated casting ring was in position with the appropriate flux, the machine was released and the spring triggered the rotational motion. Optimal operating conditions were determined for each alloy. Before the Ag-Zn-Sn-In alloy was cast, the invested mould was kept in the furnace at 400°C for 5 min. The two alloys were melted with a natural gas/arc torch reducing flame as the manufacturer suggested. The temperature of the molten metal was not measured. Four castings were made for each group, providing a total of 16 crown castings, which were allowed to bench cool and then divested manually. The residual investment was carefully removed, and the castings were cleaned in distilled water for 10 min in an ultrasonic cleaner (Bransonic 2510 J-MTH).

After the sprue rod was cut, each cast specimen was positioned in the center of a ring filled with silicone elastomeric material (Examix Fine injection/putty type). After setting, the impression was removed from the ring and cut into four equal segments with a sharp razor blade. The sections of the impression were gold sputter-coated, examined at 100 X with a scanning electron microscope (SEM, JSM-T 330) operating at 5 kV, and photographed digitally on a scale of 100 mm. Using the enlarged photographic images, the mould filling index was determined as the missing length between the round edge of the cast margin and the theoretical sharp edge, which was obtained by extending the two side lines of the triangle until they intersected. When a distorted edge was found, the radius of the margin was measured and converted to the mould filling index (d) according to the formula $d = 2.70 R$, where R is the radius of the margin[19]. Sixteen measurements for each group were statistically analyzed using a two-way analysis of variance (ANOVA). The variables were alloy and investment material. Scheffé's multiple comparisons test was applied when appropriate at a 0.05 level of significance.

RESULTS

The two-way ANOVA and Scheffé's multiple comparisons test revealed that there were significant differences in the mould filling indexes between the two alloys and the two investment materials ($p<0.05$). The mould filling index of the Ag-Pd-Cu-Au alloy was significantly worse than that of the Ag-Zn-Sn-In alloy ($p<0.05$). Also the mould filling index with a rapidly prepared gypsum-bonded investment material was significantly better than that with a conventional investment material ($p<0.05$). There were no significant differences in the indexes due to their interaction ($p>0.05$). The mean and standard deviations for the alloys and the investment materials are summarized in Table 2.

DISCUSSION

The mould filling capacity of molten metals in a cast crown is primarily different from the marginal and internal fit properties of an alloy. Although the 30-min setting expansion of the rapidly prepared gypsum-bonded investment material is more efficient at obtaining a better fit of the crown[20], how well the thin sections of the mould are filled is another matter. Although Ag-Zn-Sn-In alloy is used in posts and cores[11] and never as permanent veneer restoration material in the clinic, this alloy was selected only as a control in the present study. In posts and cores, it is not necessary to obtain good mould filling but to make slightly undersized castings to clinically allow for passive fit and cement placement.

The mould filling index of the Ag-Pd-Cu-Au alloy was worse than that of the Ag-Zn-Sn-In alloy. This finding indicates that the solidification behaviour of the two alloys must be different. The better mould filling ability of Ag-Zn-Sn-In alloy is mainly due to the lower liquidus temperature (660°C) compared with that of Ag-Pd-Cu-Au alloy (930°C). Although the mould temperatures are different, there may be a smaller temperature difference between the liquidus temperature and the mould temperature when casting Ag-Zn-Sn-In alloy compared to the Ag-Pd-Cu-Au alloy. This temperature difference prolongs the period when the Ag-Zn-Sn-In alloy is in its liquid state. We speculate that the higher fluidity of the Ag-Zn-Sn-In alloy could account for the better mould filling. The lower fluidity of the molten Ag-Pd-Cu-Au alloy may be partially due to the oxidation resulting from the interaction between the metal and the various oxides in the burnout mould material at a higher temperature, as observed in titanium casting[21]. The phenomenon of the surface colour agrees with our speculation: the surface colour of the Ag-Pd-Cu-Au alloy casting immediately after retrieval from the mould is black, whereas that of the Ag-Zn-Sn-In alloy is yellowish-silver. When an alloy is cast into a mould cavity using centrifugal force, the high density of the alloy should facilitate the ability to fill the mould cavity due to a faster flow speed of the molten metal. In this study, however, the density of Ag-Zn-Sn-In alloy was slightly less than that of Ag-Pd-Cu-Au alloy (Table 1). Thus, the density of the alloy may not be a crucial factor.

The experimental data revealed that the mould filling index of alloys cast with the rapidly prepared gypsum-bonded investment material was superior to that of the conventional investment. The gas pressure and permeability of the investment materials are definite factors in the mould filling of titanium cast in a pressure casting machine[22,23]. The relationship between the gas permeability of the moulds and the centrifugal force was of some interest. It is known that an increase in the gas permeability of the mould material, including gypsum-bonded investment, results in an increase in the castability of metal using a centrifugal casting machine[24]. It was also reported that an increase in the liquid/powder ratio of the investment material resulted in an increase of the gas permeability of the mould material[25]. However, the liquid/powder ratio of both investment materials in this study was 0.33. Thus, the reason for the superiority of the rapidly prepared gypsum-bonded investment material was not clear. Several factors may have contributed to this finding, and further investigation is needed, especially regarding the gas permeability of the rapidly prepared gypsum-bonded investment material.

The clinical significance drawn from the present study is that the use of rapidly prepared gypsum-bonded investment material is recommended to achieve good mould filling when casting Ag-Pd-Cu-Au alloy.

CONCLUSION

Proper mould filling of Ag-Pd-Cu-Au and Ag-Zn-Sn-In alloy castings can be gained by using rapidly prepared gypsum-bonded investment material.

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MANUFACTURERS' DETAILS

- Castwell M.C.12, GC Corp., Tokyo, Japan
- Miro Bright, GC Corp., Tokyo, Japan
- Cristoquick 20, GC Corp., Tokyo, Japan
- Cristobalite Micro II, GC Corp., Tokyo, Japan
- Inlay wax medium, GC Corp., Tokyo, Japan
- Inlay wax margin, GC Corp., Tokyo, Japan
- New casting liner No.13, GC Corp., Tokyo, Japan
- Vacuum Power Mixer Plus, Whip Mix Corp., Louisville, KY, USA
- KDF-009H, Denken Co., Ltd., Kyoto, Japan
- Kerr Centrifico casting machine, Kerr Manufacturing Co., Romulus, MI, USA
- Bransonic 2510 J-MTH, Branson Ultrasonics Corp., Danbury, CT, USA
- Examix Fine injection/putty type, GC Corp., Tokyo, Japan
- JSM-T 330, JEOL Inc., Tokyo, Japan

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